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PAPER

Infection rate treating radial and ulnar fractures using bone plate fixation without antibiotic prophylaxis

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Objectives: **To evaluate the effectiveness and complication rate of a 1.5- and 2.0-mm titanium locking plate for the treatment of radial and ulnar fractures in small dog breeds and cats without peri-operative antibiotic prophylaxis in a prospective case series.**

Materials and Methods: **Medical records and radiographs of closed radial and ulnar fractures treated using internal fixation with a 1.5- or 2.0-mm titanium locking plate without antibiotic prophylaxis were collected prospectively. Patients were clinically followed up until radiographical fracture healing was complete.**

Results: **Thirty-two fractures in small breed dogs and cats with an average bodyweight of 3.9 kg met the inclusion criteria. The follow-up time radiographically and clinically was 4–35 weeks. All fractures showed radiographical fracture union, and all patients had a good clinical outcome. The superficial infection rate in this case series was 0%; the deep infection rate involving the implant/bone was 3.1%.**

Clinical Significance: **The novel 1.5- and 2.0-mm titanium locking plate system was successfully used to treat simple closed radial and ulnar fractures in small breed dogs and cats without peri-operative antibiotic prophylaxis, resulting in good clinical outcome and a low infection rate.**

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INTRODUCTION

Small breed dogs have a high incidence of radial and ulnar fractures (Gibert *et al.* 2015). A variety of techniques exist for the fixation of these fractures. External skeletal fixation can be successfully used (Aikawa *et al.* 2019). However, plate and screw fixation is the most common method of fixation (Gibert *et al.* 2015). Overall, 0.8% to 18.1% of surgical sites in small animal surgery are reported to develop infections (Nelson 2011). The expected surgical site infection (SSI) rate in clean operative wounds in dogs and cats is reported to be 2.0% to 7.1% (Vasseur *et al.* 1988, Brown *et al.* 1997, Whittem *et al.* 1999, Beal *et al.* 2000, Eugster *et al.* 2004, Turk *et al.* 2015).

The development of antibiotic resistance is a growing worldwide problem, that is, one of the biggest threats to global health, food security, and development, according to the World Health Organization (WHO). All government, industrial, agricultural, and individual health care workers are urged to help prevent and control the spread of antibiotic resistance (World Health Organization, Antibiotic Resistance 2016). A leading veterinary publication on antimicrobial management has recommended the use of peri-operative antibiotics only in orthopaedic surgeries with extensive internal fracture fixation, open fracture repair, total hip prosthesis, extensive neurosurgery, or prolonged (>2 hours) surgery with a large amount of tissue manipulation (Sykes 2013). Other publications recommend antimicrobial prophylaxis in clean surgical orthopaedic procedures in general because SSI can have devastating consequences (Brown *et al.* 1997, Eugster *et al.* 2004, Verwilghen & Singh 2015). One prospective study concluded that there was a clear benefit from using peri-operative antibiotic medications with orthopaedic surgery; however, another study concluded the opposite, demonstrating that additional larger studies are necessary to refine the use of antibiotic therapy in veterinary surgery (Holmberg 1985, Whittem *et al.* 1999). Scandinavian countries have a more restrictive policy regarding peri-operative antibiotic medications with veterinary orthopaedic surgery. According to the

Swedish Veterinary Association, the use of surgical implants such as plates, screws, or pins for fractures is not in itself an indication for antibiotic prophylaxis (SVF 2009). A recent study showed that it is possible to use titanium TTA implants without antibiotic prophylaxis (Dyall & Schmökel 2017). However, further research is needed to establish a safe way to reduce antibiotic prophylaxis in veterinary orthopaedic surgery by identifying procedures suited for the restricted use of these drugs.

The purpose of this study was to evaluate the infection rate and rate of other complications when applying a 1.5- and 2.0-mm titanium locking plate during the treatment of closed radial and ulnar fractures in small breed dogs and cats without using peri-operative antibiotic prophylaxis. We hypothesised that open reduction and internal fixation of closed radius and ulna fractures with a locking titanium bone plate and screws and without the use of prophylactic antibiotics would not result in high rates of surgical site infections.

MATERIALS AND METHODS

The medical records of radial and ulnar fractures in small dogs and cats treated with a 1.5- or 2.0-mm titanium locking plate were collected in a prospective case series at the Evidensia Specialistdjursjukhuset Strömsholm from 2017 to 2020. After receiving the definitive implants from the manufacturer at the end of 2017, the prospective study started. All small dogs and cats with radial and ulnar fractures suitable for a 1.5- or 2.0-mm plate were operated on by the authors using the titanium implants. The patient was enlisted in the prospective case series if no peri- or post-operative antibiotic prophylaxis was used, the fracture was closed, and if the surgery was the first attempt to treat the radial and ulnar fracture. For the analysis of the study results, the data retrieved from medical records included breed, gender, age (months), bodyweight (kg), clinical status at follow-up visits, and the information from the follow-up controls, including the radiographs. Only cases with a complete medical journal were used in the study. All peri- and post-operative complications were recorded and divided into minor (no therapy necessary), major (therapy necessary), and catastrophic (Cook *et al*. 2010).

1.5/2.0 mm titanium locking LeiLox plate (Leibinger Medical GmbH & Co. KG)

The implants used in this study consisted of high-grade medical titanium. Plates are available as straight plates (SP), with screw holes over the full length, or as bridging plates (BP). Later the study, T-plates (TP) were also available. All plate holes are shaped to accommodate the thread of angle stable locking screw heads.

Outcome

Control of incisional healing and suture removal was performed at our hospital, or in some cases at the referring veterinary clinic, 10 to 12 days post-operatively. During all control visits, the function of the operated limb was assessed during walking and trotting. The extremity was palpated to identify pain, swelling, crepitus, and the range of motion of the elbow and carpal joint. Radiographic follow-up was performed every 4 to 6 weeks until union of the fracture was recorded. Signs of deep infection, such as abnormal periosteal reactions or lysis around the implants, were ruled out. Successful outcome of the fracture treatment was defined as bony healing with a bridging callus or fusion and disappearance of the fracture lines on follow-up radiographs. Good clinical outcome was defined as pain-free palpation and full use of the operated limb.

Anaesthesia and analgesia

After premedication with methadone (0.3 mg/kg; Methadon, Recip AB) and acepromazine (0.05 mg/kg sc; Plegicil, Pharmaxim AB), the patients were induced with propofol (4 mg/kg; Propofol-Lipuro, B. Braun Co.) and diazepam (0.1 mg/kg; Stesolid Novum, Actavis Group hf) iv, and anaesthesia was maintained with isoflurane/O_2. Standard equipment was used for monitoring the anaesthesia (ECG, capnography, blood pressure, and O_2 saturation).

The same aseptic preparation protocol was used in all the patients. After induction, the surgical sites were clipped with a sterilised clipper head and scrubbed for 3 minutes with a 4% chlorhexidine detergent (Descutan, Fresenius Kabi). The patient was moved into the surgical suite, where the clipped area was disinfected for at least a 3-minute contact time with 5 mg/mL of chlorhexidine alcohol solution (Klorhexidinsprit, Fresenius Kabi). The patient and front limb were draped with two layers of water-impermeable surgical drape, and the paw was covered with a sterile bandage. After that, all exposed skin and the sterile bandage were covered by an ioban incision drape (Ioban Incise Drape, 3M). All surgeries were done by a board-certified ECVS specialist. A standard cranial surgery approach to the radius using all Halsted's surgical principles was used to apply the plate. At least two locking screws proximal and distal of the fractures were applied. The subcutaneous tissue was closed using 3-0 or 4-0 absorbable monofilament suture material and the skin incision with a 3-0 or 4-0 non-absorbable suture material. Post-operative analgesia consisted of 0.3 mg/kg of methadone every 4 to 6 hours for 12 to 24 hours, together with an NSAID for 4 to 10 days. A post-operative soft bandage was applied for 2 to 3 days in most cases.

Antibiotics

No intra- or post-operative antibiotics were administered.

RESULTS

Forty-two consecutive radial and ulnar fractures were treated with a 1.5- or 2.0-mm LeiLox titanium locking plate during the study time. Four patients were excluded at the end of the study because they were lost to follow-up. Six patients with open fractures treated with antibiotics or having revision surgery of a previous fracture repair of the same radius and ulna were not enrolled in the study. Twenty-five fractures in dogs and seven fractures in cats were included in the study (n=32; Table 1). In three dogs, the fracture was bilateral. The fractures were in the

Table 1. Patient description, fracture type, time to bone union and used implant

Breed	Weight (kg)	Age (months)	f or m	Fracture type radius	Time to union weeks	iPlate type and size mm
Chihuahua	2.8	24	f	Distal, transverse	8	BP, 1.5
Mix	3.1	25	f	Distal, transverse	6	BP, 1.5
Chihuahua dx	1.9	20	f	Distal, transverse	5	BP, 1.5
Chihuahua sin	1.9	20	f	Distal, transverse	5	BP, 1.5
Italian whippet	5.6	30	m	Distal, transverse	5	BP, 2.0
Chinese Cr dog	3.6	18	f	Distal, transverse	4	BP, 1.5
Mix	2.5	14	f	Distal, transverse	12	SP, 1.5
ESH cat	4.0	12	mc	Distal, transverse	4	BP, 1.5
ESH cat	4.5	155	mc	Distal, transverse	11	SP, 1.5
Mix	2.5	18	f	Distal, transverse	12	BP, 1.5
Chihuahua	1.7	14	m	Distal, transverse	8	TP, 1.5
Yorkshire terrier	2	10	f	Distal, transverse	8	BP, 1.5
German spitz	4.2	7	f	Distal, transverse	8	BP, 1.5
Toy poodle	8	9	f	Midshaft, transverse	12	BP, 1.5
Toy poodle	8	9	f	Midshaft, transverse	12	SP, 1.5
Yorkshire terrier	2.5	8	f	Distal, transverse	14, infection	SP, 1.5
Italian whippet	4.4	7	m	Distal, transverse	10	BP, 2.0
Ragdoll	4.6	22	m	Distal, transverse	6	SP, 1.5
Italian whippet	4.7	19	m	Distal, transverse	8	TP, 2.0
Mix	6.2	74	mc	Midshaft, transverse	6	BP, 1.5
German spitz	3.8	4	m	Midshaft, transverse	4	BP, 1.5
Petit brabancon	3	11	f	Distal, transverse	4	TP, 1.5
Shetland sheepdog	6.7	12	f	Proximal, transverse	8	BP, 2.0
ESH cat	4.8	13	m	Midshaft, transverse	8	BP, 1.5
ESH cat	4.5	12	m	Distal, 1 fragment	8	BP, 1.5
Yorkshire terrier	2.5	7	f	Distal, transverse	8	SP, 1.5
ESH cat	4.2	31	f	Midshaft, 1 fragment	8	BP, 1.5
Chihuahua	1.9	19	m	Distal, transverse	4	TP, 1.5
ESH cat	3.5	16	fs	Midshaft, comminuted	6	BP, 1.5
Toy poodle	5.2	7	m	Distal, transverse	8	BP, 1.5
Russkiy toy dx	2.7	9	f	Midshaft, transverse	9	SP, 1.5
Russkiy toy sin	2.7	9	f	Midshaft, transverse	9	SP, 1.5

BD, bridging plate; f, female; m, male; SP, standard plate; TP, T-plate

following breeds: mixed breed dogs (n=4), Chihuahua (n=4), Italian whippet and Yorkshire terrier (each n=3), German spitz and toy poodle (each n=2), and one each of Chinese crested dog, Shetland sheepdog, Russkiy toy, and petit brabancon. Six European short-haired cats and one ragdoll were included. The study included 18 fractures in females, 10 in males, three in castrated males, and one in a spayed female patient. The average age was 20.8 months (range 4-155 months), and the average weight was 3.9 kg (range 1.7-6.7 kg).

In all the patients, the radius and ulna were fractured. The fracture configuration of the radius was as follows: 21 (66%) distal transverse, seven (22%) midshaft transverse, and one (3%) proximal transverse fracture. Two (6%) fractures had one small fragment, and one (3%) was a midshaft comminuted fracture. Twenty bridging plates, eight standard plates, and four T-plates were used (Table 1).

Outcome

The mean radiographic follow-up time was 10 weeks (range 4–35 weeks). All 32 fractures reached radiographic union and good limb function based on clinical examination (Figs 1 and 2). There was no failure of a plate or screw and no loosening of the plate-screw interface. Two patients had a radiograph 22 weeks and 35 weeks after surgery, respectively, to control the bone, showing good bone quality under the plate.

Complications

One Yorkshire terrier showed radiographic signs of osteolysis around the proximal screws in the radius repair with a 1.5 mm plate after 6 weeks (Fig 3). All implants were removed, and antibiotics orally were prescribed (clindamycin [Antiriobe vet., Orion Pharma] for 14 days) following bacteriological culture and antibiogram results revealing *Staph. pseudintermedius* on the implants. No further complications were observed at the follow-up control 14 weeks after the initial surgery. The radiographs showed good final healing of the fracture with a good function of the operated limb (Fig 3).

The overall SSI rate in the study was 3.1%.

DISCUSSION

Surgical site infections (SSI) cannot be completely prevented, and prophylactic strategies represent the most effective means of reducing their incidence. Proper preventive measures include adherence to aseptic principles and good surgical techniques, as well as proper preparation and care of the patient and the surgical area before, during, and after surgery (Nelson 2011). The infection rate depends on many pre-, peri-, and post-operative factors. Hygiene protocols are different from clinic to clinic. Orthopaedic surgical procedures have a great variation in necessary

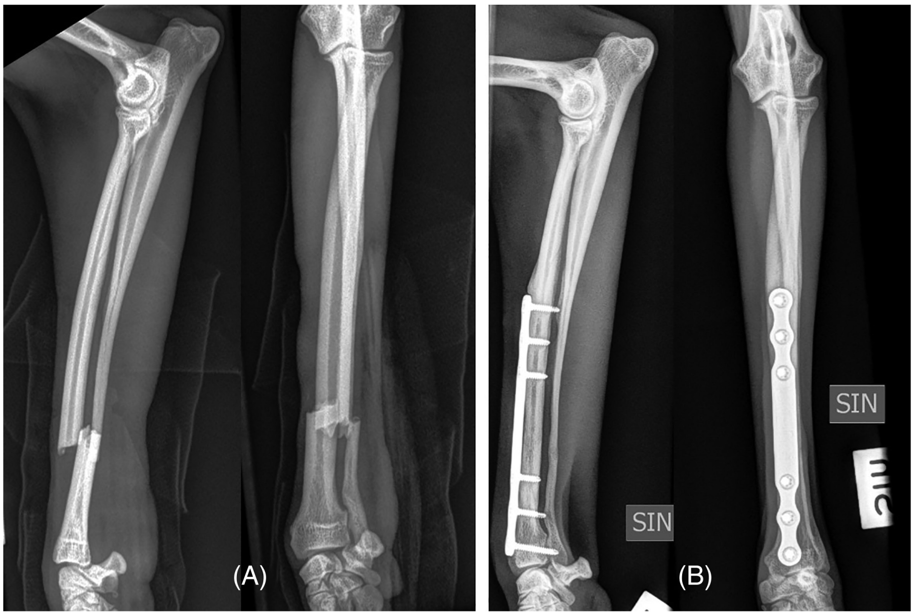

FIG 1. Distal radial and ulnar fracture in a Italian whippet: (A) pre-operative radiograph, (B) 22-weeks control radiographs showing fracture healing without signs of infection, bridging plate used

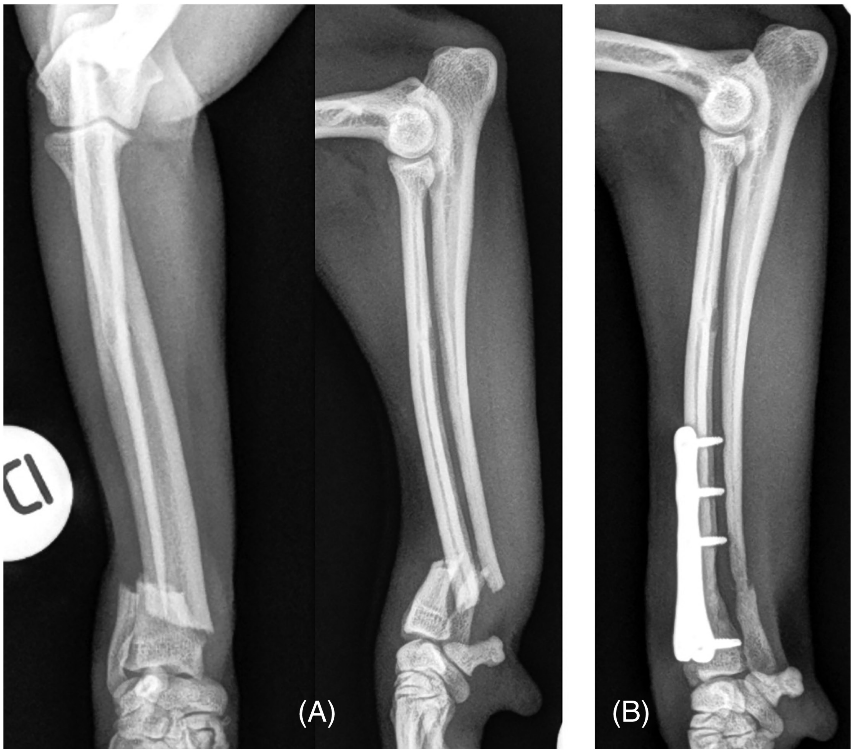

FIG 2. Distal radial and ulnar fracture in a Petit Brabancon: (A) pre-operative radiograph, (B) 8-weeks control radiographs showing fracture healing of the radius without signs of infection, T-plate used

soft-tissue trauma, length of anaesthesia, implants, and other factors. This could explain the different results and recommendations regarding SSI rates.

Prophylactic antibiotic treatment is widely used. According to a British survey performed in 2012 with small animal surgeons, 25.3% to 32.1% always used peri-operative antimicrobial drugs for clean surgeries *versus* 21.1% to 31.1% who never did. Furthermore, 31% of the surgeons agreed that antimicrobial drugs decreased wound infections in clean surgical procedures, while 22.7% agreed that all animals undergoing surgery benefit from peri-operative antibiotic drug administration (Knights *et al*. 2012). However, concerns about the development of multidrug resistance are growing (Weese 2008, Windahl et al. 2015). The identified pathogen in our infected

FIG 3. Infected radial implant in the only case with a SSI: (A) 4-weeks post-operative control radiograph showing advanced fracture healing, standard plate used. (B) 6-weeks post-operative radiograph showing bone absorption around the screws, the implants were removed a week later. A non-resistant S. *pseudintermedius* was cultured from the implants. (C) 14-weeks control radiograph showing good healing of the fracture

osteosynthesis was *Staph. pseudintermedius*, which is one of the most common pathogens in canine SSI. This bacterium can develop a dangerous multidrug resistance, the methicillin-resistant *S. pseudintermedius* MRSP (Windahl *et al.* 2015).

Titanium implants have a thicker surface oxidation layer than polished surgical steel (EPSS) implants. This allows better cell adhesion and osteointegration (Hayes & Richards 2010). This results in stronger resistance to infections, at least in experimental settings (Arens *et al.* 1996, Hauke *et al.* 1997). In clinical settings, this advantage may be less relevant as the implant design may be more important, as well as the sustained soft tissue trauma, including the iatrogenic surgical trauma (Haubruck & Schmidmaier 2017). However, other publications corroborate that titanium is a biologically superior implant material and that its performance in infected cases is clinically relevant. Tissue adherence to titanium, facilitated by the biocompatibility of the material and surface structure, avoids the formation of dead space, which promotes the deleterious propagation of bacteria and biofilm development, such as on a stainless-steel surface (Perren *et al.* 2016, Akyol *et al.* 2017).

In this study, open reduction and fixation with a titanium locking plate resulted in a good short-term outcome in all patients. The major short-term complication rate was similar to other published case series of radial and ulna fractures treated with non-locking plates (De Auburn *et al.* 2017, Watrous & Moens 2017, Aikawa *et al.* 2018), or treated with a locking plate (Gibert *et al.* 2015, Kang *et al.* 2016).

The SSI rate of 3.1% infections in this case series was not higher than expected for open fracture stabilisation (Verwilghen & Singh 2015), especially considering that no peri-operative antibiotic therapy was used. This infection rate is comparable with the SSI rate reported using the titanium TTA rapid implants (SSI 2%) and hemi-/laminectomies (SSI 0.6%) without prophylactic antibiotic therapy (Dyall & Schmökel 2017, 2018). However, it is not possible to attribute the low SSI only to the titanium material, because many other factors influence the SSI (Verwilghen & Singh 2015, Haubruck & Schmidmaier 2017). The larger part of the treated fractures in this study was simple transverse in the distal part of the radius, indicating a minor trauma as the cause. In fact, most of these younger and otherwise healthy patients sustained a fall from the owner's arms or some similar height. This results in minor soft tissue trauma at the beginning. The healing rate and SSI in more comminuted radial and ulna fractures treated with these titanium implants will need to be evaluated in a further study.

The limited bone surface contact in these small bones, and limited peri-osseous soft-tissue coverage with poor blood supply, make distal radial and ulnar fractures especially challenging regarding non-unions (Welch *et al.* 1997). Non-union and infections are often seen in unstable fracture fixations. The low rate of SSI and the high rate of fast fracture union allow the conclusion that the applied implants provided enough stability for healing.

The study was designed as a prospective consecutive case series, but some limitations remain. The precise time point of the bony union could not be given in our study because of inconsistent radiographic follow-up in some cases; however, all fractures reached radiographic bony union within the individual follow-up. Objective measurement of limb function was not available. The functional outcome was based on clinical examination in our hospital.

As it is the decision of our hospital leadership, backed up by a clear government policy, to reduce the use of prophylactic antibiotics, we have no control group with peri- and post-operative antibiotic prophylaxis.

A further limitation is the fact that the cases had no minimum one-year follow-up. Surgical site infections are defined as infections that occur within 30 days after surgery. Some definitions, however, include infections 1 year post-operatively if an implant is placed and infection appears to be related to surgery (Centers of Disease Control and Prevention 2020). However, all patients had a follow-up until fracture healing, making it possible to recognise significant post-operative infections during the short-term follow-up until fracture healing.

In conclusion, a 1.5- and 2.0-mm titanium locking plate system was successfully used to treat simple closed radial and ulnar fractures in small breed dogs and cats without peri-operative antibiotic prophylaxis. A low SSI rate and good functional outcome in all patients were recorded during this prospective case study.

Conflict of interest

One author (HS) has been involved in LeiLox system courses. Otherwise no funding has been received.

References

Aikawa, T., Miyazaki, Y., Lizuka, K., *et al*. (2018) Clinical outcome and complications after open reduction and internal fixation utilizing conventional plates in 65 distal radial and ulnar fractures of miniature- and toy-breed dogs. *Veterinary Comparative Orthopaedics and Traumatology* **3**, 214-217

Aikawa, T., Miyazaki, Y., Saitoh, Y., *et al*. (2019) Clinical outcome of 119 miniature- and toy-breed dogs with 140 distal radial and ulnar fractures repaired with free-form multiplanar type II external skeletal fixation. *Veterinary Surgery* **48**, 938-946

Arens, S. T., Schlegel, G., Ziegler, W. J., *et al*. (1996) Influence of materials for fixation implants on local infection. An experimental study of steel versus titanium DC-plates in rabbits. *Journal of Bone and Joint Surgery* **78**, 647-651

Akyol, S., Bozkus, H., Adin, S., *et al*. (2017) Which is better: stainless steel or titanium alloy? *Turkish Neurosurgery* 1-7. https://doi.org/10.5137/1019-5149.JTN.19061-17.1

Beal, M. W., Brown, D. C. & Shofer, F. S. (2000) The effects of perioperative hypothermia and the duration of anaesthesia on postoperative wound infection rate in clean wounds: a retrospective study. *Veterinary Surgery* **29**, 123-127

Brown, D. C., Conzemius, M. G., Shofer, F., *et al*. (1997) Epidemiologic evaluation of postoperative wound infections in dogs and cats. *Journal of the American Veterinary Medical Association* **210**, 1302-1306

Centers of Disease Control and Prevention. (2020) Guidelines library. https://www.cdc.gov/ HAI/ssi/ssi.html. Accessed May 15, 2021.

Cook, J. R., Evans, R., Conzemius, M. G., *et al*. (2010) Proposed definitions and criteria for reporting time frame, outcome, and complications for clinical studies in veterinary medicine. *Veterinary Surgery* **39**, 905-908

De Auburn, R., Benamou, J., Gatineau, M., *et al*. (2017) Open reduction and cranial bone fixation of fractures involving the distal aspect of the radius and ulna in miniature- and toy-breed dogs: 102 cases (2008-2015). *Journal of the American Veterinary Medical Association* **250**, 1419-1426

Dyall, B. & Schmökel, H. (2017) Tibial tuberosity advancement in small-breed dogs using TTA rapid implants: complications and outcome. *Journal of Small Animal Practice* **58**, 314-322

Dyall, B. & Schmökel, H. (2018) Surgical site infection rate after hemilaminectomy and laminectomy in dogs without perioperative antibiotic therapy. *Veterinary Comparative Orthopaedics and Traumatology* **31**, 202-213

Eugster, S., Schawalder, P., Gaschen, F., *et al*. (2004) A prospective study of post-operative surgical site infections in dogs and cats. *Veterinary Surgery* **33**, 542-550

Gibert, S., Ragetly, G. R. & Boudrieau, R. J. (2015) Locking compression plate stabilization of 20 distal radial and ulnar fractures in toy and miniature breed dogs. *Veterinary Comparative Orthopaedics and Traumatology* **28**, 441-447

Haubruck, P. & Schmidmaier, G. (2017) Susceptibility to infections and behavior of stainless steel: comparison with titanium implants in traumatology. *Unfallchirurg* **120**, 110-115

Hauke, C., Kahn, I. M., Archer, C. W., *et al*. (1997) Local infection in relation to different implant materials. An experimental study using stainless steel and titanium solid, unlocked intramedullary nails in rabbits. *Orthopaedic Transactions (of the Orthopaedic Research Society)* **21**, 835-836

Hayes, J. S. & Richards, R. G. (2010) The use of titanium and stainless steel in fracture fixation. *Expert Review of Medical Devices* **7**, 843-853

Holmberg, D. L. (1985) The use of prophylactic penicillin in orthopaedic surgery: a clinical trial. *Veterinary Surgery* **14**, 160-165

Kang, B.-J., Ryu, H.-H., Park, S., *et al*. (2016) Clinical evaluation of a mini locking plate system for fracture repair of the radius and ulna in miniature breed dogs. *Veterinary Comparative Orthopaedics and Traumatology* **29**, 522-527

Knights, C. B., Mateus, A. & Baines, S. J. (2012) Current British veterinary attitudes to the use of perioperative antimicrobials in small animal surgery. *Veterinary Record* **170**, 646-653

Nelson, L. L. (2011) Surgical site infections in small animal surgery. *Veterinary Clinics of North America: Small Animal Practice* **41**, 1041-1056

Perren, S.M., Regazzoni, P. & Fernandez, A.A. (2016) Titanium vs steel in trauma surgery. Part II: Biological aspects. *ICUC paper* https://www.researchgate.net/publication/313903719. Accessed May 15, 2021

Sveriges Veterinärförbunds antibiotika policy for hund- och kattsjudvård. (2009) https://www.svf.se/media/wtjjdi3e/antibiotikapolicy-hundokatt_2009.pdf. Accessed May 15, 2021

Sykes, J. (2013) Antimicrobial drug use in dogs and cats. In: Antimicrobial Therapy in Veterinary Medicine. 5th edn. Eds S. Giguère, J. F. Prescott and P. M. Dowling. John Wiley & Sons Inc., Ames, Iowa, USA. pp 473-494

Turk, R., Singh, A. & Weese, J. S. (2015) Prospective surgical site infection surveillance in dogs. *Veterinary Surgery* **44**, 2-8

Vasseur, P. B., Levy, J., Dowd, E., *et al*. (1988) Surgical wound infection rates in dogs and cats. Data from a teaching hospital. *Veterinary Surgery* **17**, 60-64

Verwilghen, D. & Singh, A. (2015) Fighting surgical site infections in small animals: are we getting anywhere? *Veterinary Clinics of North America: Small Animal Practice* **45**, 243-276

Watrous, G. W. & Moens, N. M. M. (2017) Cuttable plate fixation for small breed dogs with radius and ulna fractures: retrospective study of 31 dogs. *Canadian Veterinary Journal* **58**, 377-382

Weese, J. S. (2008) Review of multidrug resistant surgical site infections. *Veterinary Comparative Orthopaedics and Traumatology* **21**, 1-7

Welch, J. A., Boudrieau, R. J., DeJardin, L. M., *et al*. (1997) The intraosseous blood supply of the canine radius: implications for healing of distal fractures in small dogs. *Veterinary Surgery* **26**, 57-61

Windahl, U., Bengtsson, B., Nyman, A.-K., *et al*. (2015) The distribution of pathogens and their antimicrobial susceptibility patterns among canine surgical wound infections in Sweden in relation to different risk factor. *Acta Veterinaria Scandinavica* **57**, 11. https://doi.org/10.1186/s13028-015-0102-6

Whittem, T. L., Johnson, A. L., Smith, C. W., *et al*. (1999) Effect of perioperative prophylactic antimicrobial treatment in dogs undergoing elective orthopedic surgery. *Journal of the American Veterinary Medical Association* **215**, 212-216

World Health Organization (WHO). (2016) Antibiotic resistance fact sheet, October 2016. http://www.who.int/mediacentre/factsheets/antibiotic-resistance/en/. Accessed May 15, 2021